Walchand College of Engineering, Sangli

(Government Aided Autonomous Institute)

Course Contents (Syllabus) for

First Year M. Tech (Civil Structural Engineering) Sem. I to II

AY 2020-21

Title of the Course: Research Methodology (4IC501)	L	T	P	Cr
	2	-	-	2

Desirable Courses: NA

Textbooks:

1. Wayne, G. and Melville S., "Research Methodology: An Introduction", Juta and Company Ltd., 2nd Edition, 2004.
2. Kumar Ranjit, "Research Methodology: A Step by Step Guide for beginners", SAGE Publications, 4th Edition, 2014.
3. Melville Stuart and Goddard Wayne, "Research Methodology: An Introduction for Science & Engineering Students" Juta and Company Ltd, 2000.

References:

1. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
2. Mayall, "Industrial Design", McGraw Hill, 1992.
3. Ramappa T., "Intellectual Property Rights Under WTO", S. Chand, 2008.

Course Objectives:

1. To prepare students for undergoing research, identify and formulate the research problems, state the hypothesis, design a research layout, set a research process and methodology.
2. To enable students to investigate the problem, interpret the results, propose theories, suggest possible/alternative solutions, solve and prove the solution adapted–logically and analytically, conclude the research findings.
3. To impart knowledge to analyze critically the literature and publish research in conferences, journals and to expose students to research ethics, IPR.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Analyze** research and its significance in economic, social and legal aspects.	III	Analyzing
CO2	**Discuss** research problem and its design for solution logically and critically.	V	Evaluating
CO3	**Produce** research solution, publication, Dissertation, IPR and patent doc.	VI	Creating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1	**2**				**2**	
CO2		**2**	**2**		**3**	
CO3	**2**	**2**			**2**	

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	**Marks**

ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:	
Module 1: Engineering Research process	**6 Hrs.**
Meaning of research problem, Sources of research problem, Criteria and Characteristics of a good research problem, Errors in selecting a research problem, Definition, scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations.	
Module 2: Research methodology	**8 Hrs.**
Problem statement formulation, resources identification for solution, Experimental and Analytical modelling, Numerical and Statistical methods in engineering research, Software tools like spread sheets, Effective literature studies approaches, critical analysis.	
Module 3: Effective Technical Writing	**6 Hrs.**
Plagiarism, Research ethics, Effective technical writing, how to write report, Paper. Presentation of paper/report/seminar.	
Module 4: Patents and IPR	**8 Hrs.**
Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies.	
Module wise Outcomes At end of each module students will be able to: 1. Formulate and analyze the research problems, state the hypothesis, design a research layout, set a research process and methodology. 2. Evaluate research tools to obtain solution to research problem. 3. Analyze critically existing literature and prepare seminar, write research article and report. 4. Create IPR in his domain of research and produce patent.	

Title of the Course: Mechanics of Structures (4ST501)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Solid Mechanics, Structural Mechanics I, Structural Mechanics II

Textbooks:

1. Vazirani. V.N. & Ratwani M.M., "Advanced Theory of Structures", Khanna Publishers, 2008.
2. Timoshenko. S. P. & Gere. J. M., "Theory of Elastic Stability", Tata McGraw-Hill Publishing Company Ltd., 2nd Edition,1985.
3. Gere. J. M. & Weaver. W., "Matrix Analysis of Framed Structures", CBS Publishers and Distributor, 2nd Edition,2004.

References:

1. Mcquire and Gallghar. R. H. "Matrix Structural Analysis", John Wiley, 2nd Edition, 2000.
2. Beaufit F.W et al. "Computer Methods of Structural Analysis", Prentice Hall, illustrated,1970.
3. John L. and Meek, "Matrix Structural Analysis", Mc Graw Hill Book Company, illustrated,1971.

Course Objectives:

1. To impart the knowledge of advanced methods of structural analysis.
2. To provide knowledge for analyzing special types of structures.
3. To prepare students to develop computer programs by using matrix methods of structural analysis.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Apply** advanced methods for analysis of structures.	III	Applying
CO2	**Calculate** forces and displacements for special structures.	IV	Evaluating
CO3	**Formulate** program by using matrix methods of structural analysis for field applications.	VI	Creating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1	**2**		**2**	**2**		**2**
CO2			**3**	**3**		**2**
CO3	**2**		**2**	**2**		**2**

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	**Marks**
ISE 1	10
MSE	30

ISE 2	10	
ESE	50	
ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc. MSE: Assessment is based on 50% of course content (Normally first three modules) ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.		
Course Contents:		
Module 1: Influence line Diagrams for Indeterminate Structures		**8 Hrs.**
Influence line Diagrams for Indeterminate Structures: Muller-Breslau's Principle I.L.D. for Continuous beams and two hinged arches.		
Module 2: Beams Curved in Plan		**7 Hrs.**
Beams Curved in Plan: Analysis of determinate & indeterminate beams curved in plan.		
Module 3: Beams on Elastic Foundations		**7 Hrs.**
Beams on Elastic Foundations: Analysis of infinite, semi-infinite & finite beams.		
Module 4: Beam Columns		**8 Hrs.**
Beam Columns: Concept of geometric & material nonlinearity, Governing differential equation. Analysis of beam-columns subjected to different loadings and support conditions. Buckling of frames–symmetrical and unsymmetrical, Stiffness and carry-over factors for beam-columns, fixed end actions due to various loads.		
Module 5: Flexibility Method		**7 Hrs.**
Flexibility Method: Element approach, Flexibility matrix, Equivalent loads, Applications to beams, frames and trusses, Lack of fit, Temperature stresses.		
Module 6: Stiffness Methods		**8 Hrs.**
Stiffness Methods: Matrix methods, Element approach, Stiffness matrix, Equivalent loads, Applications to beams, frames and trusses, direct stiffness method.		
Module wise Outcomes At end of each module students will be able to: 1. Construct ILD for various structural quantities for statically indeterminate structure. 2. Analyze beams curved in plan and construct its BMD and TMD. 3. Analyze beams on elastic foundations with different boundary condition and loading. 4. Apply beam - column concept for analysis of frames. 5. Analyze structural system using element approach of flexibility method 6. Formulate algorithm to solve structural systems using matrix methods of structural analysis.		

Title of the Course: Structural Dynamics and Earthquake Engineering (4ST502)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Engineering Mathematics, Geology

Textbooks:

1. Clough R. W. and Penziene Joseph, "*Dynamics of Structures*", McGraw Hill Education (ISE Editions); International 2 Revised edition August 1993.
2. Chopra A.K., "*Dynamics of Structure: Theory & Application to Earthquake Engineering*", Pearson Education Lim., 4th Edition, 2014
3. Agarwal P. and Shrikhande M., "*Earthquake Resistant Design of Structures*", PHI Learning Pvt. Ltd., 2006.

References:

1. Key David, "*Earthquake Design Practice for Buildings*", Thomas Telford Publication London, 2nd Edition, 2006.
2. Dowrick D. J., "*Earthquake Resistant Design for Engineers & Architects*", John Wiley & Sons., 2nd Edition, 1987.
3. Manual of "Earthquake Resistant Non-Engineering Construction", University of Roorkee, 2000.

Course Objectives:

1. To impart knowledge of ground motion characteristics and its effect on Civil Engineering structures.
2. To prepare students to solve problems on dynamics of structures in SDOF and MDOF Systems.
3. To illustrate national and global codal provisions for design of earthquake resistant structures and implementation of same for seismic retrofit.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Use** engineering seismology and its characteristics for development of response spectra.	III	Applying
CO2	**Estimate** response of structures subjected to earthquake loads for various building configurations.	IV	Analyzing
CO3	**Evaluate** forces for design of earthquake resistant structure.	V	Evaluating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1	**1**		**2**	**3**		**2**
CO2	**1**		**3**	**2**		**2**
CO3			**2**	**2**	**1**	**2**

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	**Marks**

ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Seismological Aspect in Earthquake Engineering	**6 Hrs.**
Characteristics of Earthquakes, Elastic rebound theory, Measurement of earthquakes, Magnitude, Intensity, magnitude relationship, Seismograph, Liquefaction. Attenuation relationship, MCE and DBE, Performance of various structures in past earthquake.	
Module 2: SDOF Systems and Estimation of Forces	**6 Hrs.**
Earthquake response of linear SDOF systems and its application in dynamic analysis. Concept of earthquake response spectrum, Tripartite plot of response spectrum, Construction of design response spectrum. Use of Code Spectra to find response of structures. Equivalent static method to find story shear and its distribution along height of building.	
Module 3: MDOF Systems and Dynamic Analysis	**7 Hrs.**
Earthquake response of linear MDOF systems, Modal analysis, Participation factors, Modal contributions, Dynamic analysis of Multistoried buildings.	
Module 4: ERD of Structure and Roll of Ductility	**7 Hrs.**
Concept of earthquake resistant design, Objectives, Ductility and different types of ductility. Over strength, Response reduction factor, Ductile Detailing of structural components as per code. lateral stiffness, Conceptual design, Building configuration.	
Module 5: Distribution of Lateral Forces and Codal Provisions	**6 Hrs.**
Floor diaphragm, Rigid floor diaphragm, Center of mass and center of stiffness, Torsionally un-coupled and coupled systems, Lateral load distribution, Minimum eccentricity, Provisions of IS: 1893 for buildings, Base shear, Application to Multistory buildings, Load combinations, Ductile detailing, Provisions of IS: 13920.	
Module 6: Structural Control and Retrofit Issues	**7 Hrs.**
Different lateral load resisting systems, Configuration of tall structures with modeling. Nonlinear analysis of structures. Concepts of structural Control, Energy dissipating devices. Retrofit issues and their solutions with advanced techniques.	

Module wise Outcomes

At end of each module students will be able to:

1. Use concept of seismology and attenuation relations to find EPGA.
2. Estimate response of SDOF system under various dynamic forcing functions.
3. Evaluate dynamic response of MDOF systems.
4. Apply the concept of earthquake resistant ductile design.
5. Compute torsional shear as per codal provision in multistoried building frames.
6. Apply structural control measures and promising retrofit techniques with procedure.

Title of the Course: Modern Materials and Testing Laboratory (4ST551)	L	T	P	Cr
	-	-	4	2

Desirable Courses: Concrete Technology

Textbooks:

1. Gambhir M. L., "Concrete Technology", Tata McGraw Hill Publications, 3rd Edition 2004.
2. Shetty M. S., "Concrete Technology", S. Chand Publications, Latest Edition 2005.
3. Santhakumar A. R., "Concrete technology", Oxford Higher Education/Oxford University Press, 1st Edition 2006.

References:

1. Neville A. M., "Concrete Technology", Addision Weslley.
2. Neville A.M., "Properties of Concrete", Pitman, 1968.
3. Lue F.M., "Chemistry of Cement and Concrete", Edward Arnold, 3rd Edition, 1970.

Course Objectives:

1. To provide students the necessary knowledge of Properties & techniques of Mix design of advanced types of concrete.
2. To provide the technical information of modern concrete such as SCC, RMC, FRP, FRC and HPC etc.
3. To inculcate the information of structural health monitoring for repair and rehabilitation structures and the various concepts and testing methods adopted in non-destructive testing of concrete.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Study** of mix design for high performance of concrete of various grades.	IV	Analyzing
CO2	**Evaluate** experimentally properties of various advanced concretes.	V	Evaluating
CO3	**Design** experiments for vibration measurements & data acquisition system.	VI	Creating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	1	2	3	4	5	6
CO1	2		1	3		2
CO2			2	2		2
CO3	2		2	1	1	2

Assessments:

Teacher Assessment:

There are four components of lab assessment, LA1, LA2, LA3 and Lab ESE.

IMP: Lab ESE is a separate head of passing.

Assessment	Based On	Conducted By	Conduction and Marks Submission	Marks

LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 4 Submission at the end of Week 5	25
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 5 to Week 8 Submission at the end of Week 9	25
LA3	Lab activities, attendance, journal	Lab Course Faculty	During Week 10 to Week 14 Submission at the end of Week 14	25
Lab ESE	Lab Performance and related documentation	Lab Course faculty	During Week 15 to Week 18 Submission at the end of Week 18	25

Week 1 indicates starting week of Semester.

Lab activities/Lab performance shall include performing experiments, mini-project, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course.

Course Contents:

List of Experiments:

1. Evaluate of static and dynamic modulus of elasticity of concrete and strain measurement.
2. Evaluate of flexural strength of concrete.
3. Evaluate Mix Design by I.S. Code method (with OPC Cement).
4. Evaluate Mix Design by I.S. Code method (with Slag Cement).
5. Evaluate Mix Design by I.S. Code method (with Admixtures Cement).
6. Determination of Grading curve of Mix aggregate & sieve analysis.
7. Non-destructive testing of concrete.
8. Determination of Poisson's ratio of concrete.
9. Determination of properties of SCC, RMC, FRP, FRC and HPC.
10. Experiments based on Vibration measurements and data acquisition system.

Module wise Outcomes

Title of the Course: Dynamics of Structures Laboratory (4ST552)	L	T	P	Cr
	-	-	4	2

Desirable Courses: Structural Dynamics and Earthquake Engineering

Textbooks:

1. Clough R. W. and Penziene J., "Dynamics of Structures", McGraw Hill Pub.
2. Craig Roy, "Structural Dynamics", John Willey & Sons.
3. Chopra A. K., "Dynamics of Structures - Theory & Application to Earthquake Engineering", Prentice Hall Pub.

References:

1. Mukhopadhyay. "Dynamics of Structures", Ane books Pvt Ltd, 2nd edition 2010.
2. Paz Mario, "Structural Dynamics", CBS Publishers and Distributers, 5th edition 2003.
3. Jaikrishna A. R. and Chandra Brijesh, "Elements of Earthquake Engineering", South Asian Publishers Private Limited, 2nd Edition, 2000.

Course Objectives:

1. To impart knowledge of SDOF system under various dynamic loading by solving different types of problems.
2. To illustrate behavior of MDOF system under various dynamic loading by solving different types of problems by conducting experiments
3. To provide knowledge of behavior of distributed mass model by conducting experiments.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Apply** principles of dynamics to solve SDOF and MDOF systems.	III	Applying
CO2	**Appraise** behavior of discrete system.	IV	Analyzing
CO3	**Evaluate** behavior of continuous system and **judge** effect of sloshing and liquefaction.	V	Evaluating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1			**2**	**3**		**2**
CO2	**1**		**2**	**2**		**2**
CO3	**1**		**3**	**2**		**2**

Assessments:

Teacher Assessment:

There are four components of lab assessment, LA1, LA2, LA3 and Lab ESE.

IMP: Lab ESE is a separate head of passing.

Assessment	**Based On**	**Conducted By**	**Conduction and Marks**	**Marks**

			Submission	
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 4 Submission at the end of Week 5	25
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 5 to Week 8 Submission at the end of Week 9	25
LA3	Lab activities, attendance, journal	Lab Course Faculty	During Week 10 to Week 14 Submission at the end of Week 14	25
Lab ESE	Lab Performance and related documentation	Lab Course faculty	During Week 15 to Week 18 Submission at the end of Week 18	25

Week 1 indicates starting week of Semester.

Lab activities/Lab performance shall include performing experiments, mini-project, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course.

Course Contents:

List of Experiments: (Any eight experiments in addition to the assignments)

1. Assignments on each module of structural dynamics and earthquake engineering course.
2. Dynamics of a three storied building frame subjected to harmonic base motion.
3. Dynamics of a one-storied building frame with planar asymmetry subjected to harmonic base motions.
4. Dynamics of a three storied building frame subjected to periodic (non-harmonic) base motion.
5. Vibration isolation of a secondary system.
6. Dynamics of a vibration absorber.
7. Dynamics of a four storied building frame with and without an open ground floor.
8. Dynamics of one-span and two-span beams.
9. Earthquake induced waves in rectangular water tanks.
10. Dynamics of free-standing rigid bodies under base motions.
11. Seismic wave amplification, liquefaction and soil-structure Interactions.

Module wise Outcomes

Title of the Course: Professional Elective 1 Theory of Elasticity and Plasticity (4ST511)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Solid Mechanics

Textbooks:

1. Ameen M., "Computational Elasticity", Alpha Science International, 1st Revised Edition, 2008.
2. Singh Sadhu, "Theory of Elasticity", Khanna Publishers, 4th Edition, 2012.
3. Singh Sadhu, "Theory of Plasticity", Khanna Publishers, 3rd Edition, 2013.

References:

1. Timoshenko. S & Goodier. J. N., "Theory of Elasticity", McGraw-Hill book Company, 3rd Edition, 2010.
2. Chakrabarthy. J, "Theory of Plasticity", Tata McGraw-Hill P. Co. Ltd., 2nd Edtion, 2007.
3. Johnson W. and Mellor P. B., "Engineering Plasticity", Van Nostrand Reinhold, London, 1973.

Course Objectives:

1. To impart knowledge of various theories of elasticity and apply them to solve 2D Cartesian and polar problems.
2. To impart knowledge of various theories of torsion and apply them to solve 2D torsional problems.
3. To provide knowledge of various theories of plastic behavior and apply them to solve 2D problems.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Apply** the knowledge of fundamental methods of elasticity for 2-D Cartesian and Polar problems.	III	Applying
CO2	**Analyze** torsional problems and apprise various theories to solve 2-D torsional problems.	IV	Analyzing
CO3	**Discuss** concept of material yielding and plastic behavior of structures.	V	Evaluating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1	**1**		**2**	**2**		**2**
CO2			**2**	**3**		**2**
CO3	**1**		**2**	**2**		**2**

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	**Marks**
ISE 1	10
MSE	30

ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Introduction to Elasticity	**8 Hrs.**
Introduction to Elasticity: Body force, Surface force, Stress at a point, Stress & Strain, Transformation of stress, Equilibrium equations in two and three dimensions in Cartesian co-ordinates, Boundary conditions, Strain displacement relations, Compatibility equations, Generalized Hooke’s Law, Stress invariants.	
Module 2: Plane Stress and Strain	**8 Hrs.**
2D problems in Cartesian co-ordinates, Equations of equilibrium and compatibility, Plane stress and Plane strain problems, Airy stress function approach, 2D problems in polar coordinates, Thick walled cylinder under radial pressure, Plate with stress concentration.	
Module 3: Torsion	**7 Hrs.**
Introduction to Torsion: St. Venant’s theory, Warping function, Prandtl’s membrane analogy, Torsion of circular, thin rectangular and open section. Strain energy in axial, bending and torsion. Principal of virtual work and minimum potential energy.	
Module 4: Plasticity	**8 Hrs.**
Introduction to plasticity: Plastic behavior of solids, Idealized plastic solids, Similarities & differences when compared with elasticity, Idealized material behavior, Coulomb friction model for elasticity and plasticity.	
Module 5: Hydrostatic Stresses	**7 Hrs.**
Hydrostatic stresses, Deviatoric stresses, Invariants of deviatoric stresses, Yield criteria, Graphical representation of yield criteria, Flow rules, Stress-strain relation for perfectly plastic flow, Elastic-plastic analysis of beam in bending, Thick walled cylinder and circular shaft under torsion.	
Module 6: Plastic Analysis of Structures	**7 Hrs.**
Plastic analysis of structures – plastic hinge, Moment – curvature relation, Shape factor, Upper bound, lower bound and uniqueness theorems, Methods of analysis to find collapse loads for beams and frames.	

Module wise Outcomes

At end of each module students will be able to:

1. Apply the elastic stress-strain behavior to solve fundamental elasticity problems.
2. Apply the application of fundamentals to solve 2D problems.
3. Analyze torsional theories and apply to solve 2D torsional problems.
4. Discuss plastic stress-strain behavior to solve basic problems.
5. Discuss various criteria for material yielding and apply to various problems.
6. Analyze 2D problems for finding collapse loads.

Title of the Course: Professional Elective 1 Structural Health Monitoring and Smart Materials (4ST512)	L	T	P	Cr
	3	-	-	3

Desirable Courses:

Textbooks:

1. Daniel Balageas, Claus - Peter Fritzenam I Alfredo Guemes, Structural Health Monitoring, Published by ISTE Ltd., UK 2006.
2. Guidebook on Non-destructive Testing of Concrete Structures, Training course series No. 17, International Atomic Energy Agency, Vienna, 2002.
3. Gandhi, M.V., Thompson B. D., Smart Materials and Structures, ISBN 978-0-412-37010-6.

References:

1. Handbook on "Repair and Rehabilitation of RCC Buildings", Published by Director General, CPWD, Govt. of India, 2002.
2. Handbook on Seismic Retrofitting of Buildings, Published by CPWD & Indian Building Congress in Association with IIT, Madras, Narosa Publishing House, 2008.

Course Objectives:

1. To impart knowledge of smart materials.
2. To illustrate principles of structural health monitoring.
3. To provide quantitative means to assess the structural integrity loss a system undergoes after natural disasters and other hazardous events.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Apply** knowledge of smart materials and techniques to SHM	III	Applying
CO2	**Appraise** structural conditions by various techniques of SHM.	IV	Analyzing
CO3	**Assess** civil engineering structures by SHM techniques and simulation.	V	Evaluating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1	**1**		**2**	**3**		**2**
CO2			**3**	**2**		**2**
CO3				**3**	**2**	**2**

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	**Marks**
ISE 1	10
MSE	30

ISE 2	10	
ESE	50	
ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc. MSE: Assessment is based on 50% of course content (Normally first three modules) ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.		
Course Contents:		
Module 1: Introduction to Smart Materials and Their Applications		**7 Hrs.**
Emerging SHM Technologies using Piezo Sensors,SHM using Magnetstrictive Sensors SHM using Optical Fibres and other sensors Overview of Application Potential of SHM. **Piezoelectric materials** (Constitutive relation, unimorph, bi-morph, Electromechanical coefficient, resonance/anti-resonance), **Electrostrictive materials** (Constitutive relation, sensor, actuator, figures of merit), **Magnetostrictive materials** (Constitutive relation, sensor, actuator, figures of merit), **Shape Memory Alloys** (Constitutive relation, transition temperatures, shape memory effect, pseduoelasticity, sensor, actuator), **Optical Fiber** (Fiber Bragg grating, strain sensing, ultrasonic sensing).		
Module 2: Introduction to Structural Health Monitoring (SHM)		**6 Hrs.**
Definition & motivation for SHM, SHM - a way for smart materials and structures, SHM and bio mimetic - analog between the nervous system of a man and a structure with SHM, SHM as a part of system management, Passive and Active SHM, NDE, SHM and NDECS, basic components of SHM, materials for sensor design.		
Module 3: Condition Survey & NDE of Civil Structure		**7 Hrs.**
Definition and objective of Condition survey, stages of condition survey (Preliminary, Planning, Inspection and Testing stages), possible defects in concrete structures, quality control of concrete structures - Definition and need,Quality control applications in concrete structures, NDT as an optionfor Non-Destructive Evaluation (NDE) of Concrete structures, case studies of a few NDT procedures on concrete structures, **Non Destructive Testing of Concrete Structures:** Introduction to NDT - Situations and contexts, where NDT is needed, classification of NDT procedures, visual Inspection, half-Cell electrical potential methods, Schmidt Rebound Hammer Test, resistivity measurement, electromagnetic methods, radiographic Testing, ultrasonic testing, Infra-Red thermography, ground penetrating radar, radio isotope gauges, other methods.		
Module 4: SHM of Composite Structures		**7 Hrs.**
Introduction to composites and their applications in structural Industry. Learning from failures. Various kinds of damage detection techniques. Repair &rehabilitation & retrofitting of composite structures, damage assessment of composites structures, Case studies.		
Module 5: Introduction to FE Simulations of Various SHM Techniques		**6 Hrs.**
Introduction to FE analysis of typical smart materials. Applications of FE simulation technique, case studies 1) Metallic structures 2) Composite structures.		

Module 6: Advanced Signal Processing	6 Hrs.
Methods for Data processing and Result interpretation, Wavelet, Neural networks, Vector support machine.	
Module wise Outcomes At end of each module students will be able to: 1. Analyze Smart Materials in SHM. 2. Apply principles of SHM. 3. Appraise condition of civil engineering structures. 4. Assess condition of composite Structures by SHM techniques. 5. Apply FE simulations in SHM 6. Analyze signal processing methods for data processing and result interpretation.	

Title of the Course: Professional Elective 2 Advanced Design of Reinforced Concrete Structures (4ST515)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Design of Concrete Structures I, Design of Concrete Structures II

Textbooks:

1. Ramamruthm, S., "Design of Reinforced Concrete Structures", Dhanpat Rai Publishing, 17th Edition, 2010.
2. Shah V. and Karve S., "Limit State Theory and Design of Reinforced Concrete", Structures Publications, 4th Edition, 2003.
3. Punmia, B. C., Jain, A. K. and Jain, A. K. "Limit State Design of Reinforced Concrete", Laxmi Publication, 1st Edition, 2013.

References:

1. Purushothaman, P. "Reinforced Concrete Structural Elements", Tata McGraw Hill, 3rd Edition, 2004.
2. Pillai. S. V. and Menon. D, "Reinforced Concrete Design", Tata McGraw Hill Book Co., 5th Edition, 2005.
3. Park. R and Paulay. T, "Reinforced Concrete Structures", John Wiley and Sons, 1975.

Course Objectives:

1. To provide advanced knowledge for analyzing different kinds of RC structures.
2. To impart advanced knowledge for design of different kinds of RC structures using IS codes.
3. To provide advanced knowledge for detailing of the structural members designed as per IS codes.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	Descriptor
CO1	**Analyze** various reinforced concrete structures	IV	Analyzing
CO2	**Size up** structural details of components of structures	V	Evaluating
CO3	**Design** the appropriate section for structural members using codal provisions	VI	Creating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	1	2	3	4	5	6
CO1	1		3	2		2
CO2		2				2
CO3			2	2	2	3

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	Marks

ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Flat Slab	**7 Hrs.**
Analysis and Design of Flat Slab, Grid floors – Approximate method for small span grids, Circular Slabs.	
Module 2: Combined Footing	**6 Hrs.**
Design of Combined footing, (Rectangular, Trapezoidal and strap footing).	
Module 3: Raft Foundation	**6 Hrs.**
Design of Raft foundation, Pile foundation.	
Module 4: Water Tank	**7 Hrs.**
Analysis and Design of overhead water tank- Rectangular and Circular with flat bottom, Design of staging for wind and seismic loads.	
Module 5: Retaining Wall	**7 Hrs.**
Retaining Walls – Function, Theories of earth pressure, Stability of retaining wall, Reinforced concrete retaining walls, Cantilever retaining wall, Counterfort retaining wall.	
Module 6: Bunkers and Silos	**6 Hrs.**
Bunkers and Silos – Classification, Square bunkers, Circular bunkers, Silos, Lateral Pressure in silos, Airy’s theory, Shallow bins, Deep bins, Design examples.	

Module wise Outcomes

At end of each module students will be able to:

1. Analyze and design special types of slabs.
2. Design and size up different types combined footings.
3. Design and size up different types of deep footings.
4. Design and size up overhead water tanks with staging.
5. Design and size up different types of retaining walls.
6. Design and size up bunkers and silos.

Title of the Course: Professional Elective 2 Advanced Design of Steel Structures (4ST516)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Design of Steel Structures

Textbooks:

1. Vazirani V. N., and Ratwani M. M., "Steel Structures and Timber Structures", Khanna Publishers, Delhi.
2. Ramchandran, "Design of Steel Structures – Vol. II", Standard Book House, Delhi.
3. Punmia B. C., Jain A. K. and Jain A. K. "Design of Steel Structures", Firewell Media.

References:

1. Taranath B. S., "Structural Analysis and Design of Tall Buildings",McGrawhill.
2. Bekar J. F., Horne M. R., Heyman J., "Steel Skeleton Vol. II Plastic Behavior & Design", ELBS.
3. Neal B. G., "Plastic Methods of Structural Analysis", Chapter & Hall.

Course Objectives:

1. To provide the knowledge of design of steel structures such as bridges, multistory buildings and portal frames.
2. To impart the knowledge of cold formed sections and composite beams.
3. To illustrate plastic analysis and design of steel frames.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Analyze** various types of steel structures.	IV	Analyzing
CO2	**Size up** structural members to carry design loads.	V	Evaluating
CO3	**Design** various types of steel structures in field.	VI	Creating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	1	2	3	4	5	6
CO1			3	3		2
CO2				3	1	2
CO3				2	1	2

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	Marks
ISE 1	10
MSE	30

ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Foot Bridges	**7 Hrs.**
Analysis and design of foot bridges, Deck of through type bridges, Flooring system, Bracing system.	
Module 2: Cold Formed Sections	**6 Hrs.**
Cold formed light gauge steel sections, Various profiles, Stiffened and unstiffened sections, Roof sheeting, Purlins, Flexure and column behavior, IS code provisions.	
Module 3: Composite Sections	**7 Hrs.**
Composite section consisting of structural steel and concrete, Composite beams, Shear connectors, Composite decks using light gauge steel and concrete, Composite columns, IS code provisions.	
Module 4: Introduction to Plastic Analysis	**6 Hrs.**
Introduction to Plastic Analysis, Plastic bending of beam, Plastic hinge, Shape factor of cross section, Static and kinematic methods of analysis, Plastic analysis and design of propped cantilever, fixed beam and continuous beams.	
Module 5: Multistory Buildings	**8 Hrs.**
Multistory buildings, Lateral load resisting systems, Types of bracing systems, Shear wall, Inelastic analysis of multistory, multi-bay frames.	
Module 6: Low Rise Portal Frames	**7 Hrs.**
Analysis of low rise rectangular and gable portal frames, Various basic mechanisms, Combination of mechanisms, Limit state design of frames, Haunches and column bases.	

Module wise Outcomes

At end of each module students will be able to:

1. Analyze and design foot bridge.
2. Verify codal provisions for cold formed light gauge steel sections.
3. Verify codal provisions for design of composite sections.
4. Apply plastic method for analysis and design of various steel structures.
5. Analyze multistory building frames subjected to lateral loads.
6. Design low rise rectangular gable portal frames, haunches and column bases.

Title of the Course: Theory of Plates and Shells (4ST521)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Theory of Elasticity and Plasticity

Textbooks:

1. Timoshenko. S.P. And Krieger. S.W, "Theory of Plates & Shells", Tata McGraw-Hill Publishing Company Limited, 2nd Edition, 1985.
2. Ramaswamy G. S., "Design and Construction of Concrete Shell Roofs", CBS Publishers and Disributors, 1st revised Edition, 1984.

References:

1. Chandrashekhara K., "Analysis of Thin Concrete shells", Tata McGraw-Hill Publishing Company Limited, 2nd Revised Edition, 2011.
2. Flugge. W., "Stresses in Shells", 2nd Edition, Springer, Berlin, 1990.

Course Objectives:

1. To impart knowledge of plate and shell behavior under different loading and boundary conditions.
2. To discuss use of classical, approximate and numerical methods to solve plate and shell problems.
3. To provide knowledge of plate and shell modeling for practical applications.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Illustrate** the behavior of various plates and shells.	III	Applying
CO2	**Analyze** plates and shells using different methods.	IV	Analyzing
CO3	**Evaluate** structural actions for practical applications of plates and shells.	V	Evaluating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1	**1**		**3**			**2**
CO2			**2**	**3**		**2**
CO3				**3**	**1**	**2**

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	**Marks**
ISE 1	10
MSE	30

ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Bending of Circular Plates	**6 Hrs.**
Thin and Thick Plates, small and large deflection theory of thin plates - assumptions, moment-curvature relations, stress resultants, governing differential Equation for bending of plates, various boundary conditions. Bending of Circular Plates: Symmetrical loading.	
Module 2: Bending of Rectangular Plates	**6 Hrs.**
Rectangular Plates Navier's and Levy's solutions for rectangular plates of various boundary conditions and subjected to various types of loads.	
Module 3: Finite Difference Method for Plates	**8 Hrs.**
Finite Difference Method Solution of plate problems derivation of delta/ pattern/ stencil for biharmonic form for a rectangular mesh, two stage solutions, solution for various loadings and boundary conditions, use of symmetry & anti-symmetry, extrapolation formula, introduction to improved Finite Difference Technique.	
Module 4: Introduction to Shells	**6 Hrs.**
Shells Classification of shells based on geometry, thickness and loading. Thin shell theory, equation of shell surfaces, stress resultants, stress-displacement relations, compatibility and equilibrium equations.	
Module 5: Analysis of Various Shells by Membrane Theory	**8 Hrs.**
Membrane Analysis Equation of equilibrium for synclastic and anticlastic shells under self-weight and live load, equations of equilibrium in rectangular co-ordinate system. Spherical and cylindrical shells under internal pressure, Cylindrical shells-equation of equilibrium with different directrix and shells with closed ends. Cylindrical and Hyperbolic paraboloid roofs.	
Module 6: Cylindrical Shell Roofs	**6 Hrs.**
Symmetrically loaded circular cylindrical Shell-Derivation of Governing Differential Equation, resembling that for beam on elastic foundation, beam theory. Finsterwalder's Theory-Derivation of governing differential equation of 8^{th} order. D. K. J. Theory-Donnell's equation, Characteristic equation. Schorer's theory-Derivation of differential equation.	
Module wise Outcomes At end of each module students will be able to: 1. Illustrate behavior of circular plates under transverse loads. 2. Illustrate behavior of rectangular plates under transverse loads. 3. Evaluate plate behavior using numerical method of Finite Difference Method. 4. Evaluate stresses and strains in shells by membrane and bending theories. 5. Analyze various shells in field applications. 6. Analyze cylindrical shell roofs by different theories.	

Title of the Course: Finite Element Method (4ST522)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Mechanics of Structures

Textbooks:

1. Seshu P. N., "Finite Element Analysis", 2003.
2. Reddy J. N., "An Introduction to the Finite Element Method" McGraw Hill, 3rd Edition, New York, 2006.
3. Cook Robert D., Malkus David S., Plesha Michael E., and Witt Robert J., "Concepts and Applications of Finite Element Analysis", 2003.

References:

1. Bathe Klaus-Jurgen, "Finite Element Procedures in Engineering Analysis",1982.
2. Chandrupatla T. R. and Belegundu A. D., "Introduction to Finite Element in Engineering", Prentice.
3. Zienkiewicz. O. C. & Taylor. R. L., "The Finite Element Method- Vol I &Vol II Tata McGraw-Hill Publishing Company Limited, 1989, 4th Edition.

Course Objectives:

1. To impart knowledge of finite element method for 1-D, 2-D,3-D elements.
2. To discuss finite element method in structural engineering.
3. To illustrate applications of FEM for plates, shells and structural dynamics.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Implement** finite element methodology for solving 1-D, 2-D, 3-D problems.	III	Applying
CO2	**Analyze** nodal degrees of freedom and stress resultants.	IV	Analyzing
CO3	**Discuss** finite element model for solution of various field Problems.	V	Evaluating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1	**1**		**3**	**3**		**2**
CO2			**2**	**2**		**2**
CO3	**1**			**1**	**2**	**2**

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	**Marks**
ISE 1	10

MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: 1-D Elements	**8 Hrs.**
1-D Elements Basic concept of finite element analysis, Discretization, nodes, element incidences, displacement model, shape function, selection of order of polynomials, application to bars with constant and variable cross sections subjected to axial forces. Principle of minimum potential energy, variation principle, development of element stiffness matrix and nodal load vector for truss, beam and plane frame elements, Transformation of matrices, relevant structural engineering applications.	
Module 2: 2-D Elements	**6 Hrs.**
2-D Elements 2-D elements of triangular and quadrilateral shapes for plane stress and plane strain problems. Pascal's triangle, convergence requirements and compatibility conditions, shape functions, boundary conditions, element aspect ratio, applications to a continuum.	
Module 3: 3-D Elements	**6 Hrs.**
3-D Elements Development of element stiffness matrix and nodal load vector for Tetrahedron, Hexahedral elements, Ax symmetric Elements - Development of element stiffness matrix and nodal load vector.	
Module 4: Isoperimetric Elements	**6 Hrs.**
Isoperimetric Elements Shape function, Natural coordinate systems, classification of isoperimetric- subprarmatric, super parametric elements, 1-D & 2-D isoperimetric elements, Gauss-quadrature integration.	
Module 5: Plate and Shell Elements	**7 Hrs.**
Plate and Shell Elements Formation of stiffness matrix for plate bending elements of triangular and quadrilateral shapes, cylindrical thin shell elements.	
Module 6: Finite Element Applications to Structural Dynamics	**6 Hrs.**
Finite Element Applications to Structural Dynamics Formulation, Hamilton's principle, element mass matrices, evaluation of Eigen values and eigenvectors.	

Module wise Outcomes

At end of each module students will be able to:

1. Implement FEM modelling to solve 1-D problems.
2. Implement FEM modelling to solve 2-D problems.
3. Implement FEM modelling to solve 3-D problems.
4. Analyse 1-D and 2-D problems using isoperimetric element methodology.
5. Analyse problems on plates and shells by using finite element formulation.
6. Calculate dynamic quantities in vibration problems.

Title of the Course: Finite Element Laboratory (4ST571)	L	T	P	Cr
	-	-	4	2

Desirable Courses: Finite Element Method

Textbooks:

1. Seshu P. N., "Finite Element Analysis", 2003.
2. Reddy J. N., "An Introduction to the Finite Element Method", McGraw Hill, 3rd Edition, New York, 2006.
3. Cook Robert D., Malkus David S., Plesha Michael E., and Witt Robert J., "Concepts and Applications of Finite Element Analysis", 2003.

References:

1. Bathe Klaus-Jurgen, "Finite Element Procedures in Engineering Analysis", 1982.
2. Chandrupatla T. R. and Belegundu A. D., "Introduction to Finite Element in Engineering", Prentice Hall of India Private Limited, 2002, 3rd Edition.
3. Zienkiewicz O. C. & Taylor R. L., "The Finite Element Method- Vol I &Vol II Tata McGraw-Hill Publishing Company Limited, 1989, 4th Edition.

Course Objectives:

1. To impart knowledge to solve 1-D, 2-D and 3-D problems by using finite element-based software.
2. To develop critical thinking and interpretation techniques.
3. To provide training on professional EF software.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Analyze** 1-D, 2-D and 3-D problems using software.	IV	Analyzing
CO2	**Evaluate** and interpret structural quantities such as displacements, stresses, strains, and vibration characteristics of structural systems under different loadings and boundary conditions.	V	Evaluating
CO3	**Create** finite element model to solve structural engineering field problems.	VI	Creating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1			**3**	**2**		**2**
CO2	**1**		**2**	**2**		**2**
CO3	**1**			**3**	**2**	**2**

Assessments:

Teacher Assessment:

There are four components of lab assessment, LA1, LA2, LA3 and Lab ESE.

IMP: Lab ESE is a separate head of passing.

Assessment	Based On	Conducted By	Conduction and Marks Submission	Marks
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 4 Submission at the end of Week 5	25
LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 5 to Week 8 Submission at the end of Week 9	25
LA3	Lab activities, attendance, journal	Lab Course Faculty	During Week 10 to Week 14 Submission at the end of Week 14	25
Lab ESE	Lab Performance and related documentation	Lab Course faculty	During Week 15 to Week 18 Submission at the end of Week 18	25

Week 1 indicates starting week of Semester.

Lab activities/Lab performance shall include performing experiments, mini-project, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course.

Course Contents:

List of Experiments: (Any six of the following)

1. Generation and solution of Truss model problems for various loadings.
2. Generation and solution of plane frame/continuous beam model problems.
3. Generation and solution of Plane stress/strain problems in engineering field.
4. Analysis of stress concentration phenomenon.
5. Evaluating displacements, stresses and strains in 3D engineering structures.
6. Evaluate Vibration characteristics of simple beams with different boundary conditions.
7. Evaluate Novel applications involving modern geometry and/or modern materials.

Module wise Outcomes

Title of the Course: Structural Health Monitoring Laboratory (4ST572)	L	T	P	Cr
	-	-	4	2

Desirable Courses: Structural Health Monitoring

Textbooks:

1. Daniel Balageas, Claus - Peter Fritzenam I Alfredo Guemes, Structural Health Monitoring, Published by ISTE Ltd., U.K. 2006.
2. Guidebook on Non-destructive Testing of Concrete Structures, Training course series No. 17, International Atomic Energy Agency, Vienna, 2002.
3. Gandhi, M.V., Thompson B. D**.,** Smart Materials and Structures, ISBN 978-0-412-37010-6.

References:

1. Handbook on "Repair and Rehabilitation of RCC Buildings", Published by Director General, CPWD, Govt. of India, 2002.
2. Handbook on Seismic Retrofitting of Buildings, Published by CPWD & Indian Building Congress in Association with IIT, Madras, Narosa Publishing House, 2008.

Course Objectives:

1. To impart knowledge of smart materials.
2. To illustrate principles of structural health monitoring
3. To provide quantitative means to assess the structural integrity loss a system undergoes after natural disasters and other hazardous events.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Apply** knowledge of smart materials and techniques to SHM	III	Applying
CO2	**Appraise** structural conditions by various techniques of SHM.	IV	Analyzing
CO3	**Assess** civil engineering structures by SHM techniques and simulation.	V	Evaluating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	1	2	3	4	5	6
CO1	1		3	3		2
CO2	1			2	2	2
CO3	1			2	2	2

Assessments:

Teacher Assessment:

There are four components of lab assessment, LA1, LA2, LA3 and Lab ESE.

IMP: Lab ESE is a separate head of passing.

Assessment	Based On	Conducted By	Conduction and Marks Submission	Marks
LA1	Lab activities, attendance, journal	Lab Course Faculty	During Week 1 to Week 4 Submission at the end of Week 5	25

LA2	Lab activities, attendance, journal	Lab Course Faculty	During Week 5 to Week 8 Submission at the end of Week 9	25
LA3	Lab activities, attendance, journal	Lab Course Faculty	During Week 10 to Week 14 Submission at the end of Week 14	25
Lab ESE	Lab Performance and related documentation	Lab Course faculty	During Week 15 to Week 18 Submission at the end of Week 18	25

Week 1 indicates starting week of Semester.

Lab activities/Lab performance shall include performing experiments, mini-project, presentations, drawings, programming and other suitable activities, as per the nature and requirement of the lab course.

Course Contents:

List of Experiments:

1. Determination and simulation of compressive strength of Concrete elements using "Rebound Hammer Test" and validation with destructive test results.
2. Determination and simulation of compressive strength of Concrete elements using "Ultrasonic Pulse Velocity Test" and validation with destructive test results.
3. Determination and simulation of compressive strength of Concrete elements by using concrete core test.
4. Determination and simulation of characteristics of ultrasonic guided waves using Piezo sensors in various materials a) Concrete b) metallic plate c) Composite plate d) HCSS plate.
5. Damage detection of following materials and simulation
   a) Concrete b) Metallic Plate c) Composite Plate d) HCSS Plate.
6. Determination of mode shapes for undamaged cantilever beams and simulation for following materials using accelerometers (piezo) a) Metallic Plate b) Composite Plate c) HCSS Plate.
7. Determination of mode shapes for damaged cantilever beams and simulations for following materials using accelerometers (piezo) a) Metallic Plate b) Composite Plate c) HCSS Plate.
8. Determination of deflection and bending stresses of the simply supported concrete beam under static and dynamic loading and simulation using LVDT transducers and verification with theory.

Module wise Outcomes

Title of the Course: Professional Elective 3 Analysis and Design of Bridges (4ST531)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Design of Concrete Structures

Textbooks:

1. Krishna Raju N., "Design of Bridges, Oxford and IBH Publishing Co. Ltd.", New Delhi and Kolkata, 2001.
2. Jagdeesh T. R., Jayaram M. A., "Design of Bridge Structures, Prentice hall of India Pvt. Ltd.", New Delhi, 2003.
3. Johnson Victor, "Essentials of Bridge Engineering, Oxford and IBH Publishing Co. Ltd.", 5^{th} Edition, 2001.

References:

1. Raina V. K., "Concrete Bridge Practice: Construction and maintenance and rehabilitation", Tata Mc Graw Hill Publishing Company, New Delhi.
2. Raina V. K., "Concrete Bridge Practice: Analysis, design and economics", Tata Mc Graw Hill Publishing Company, New Delhi.
3. IRC Codes.

Course Objectives:

1. To provide knowledge of loads and analysis for different types of bridges.
2. To impart knowledge for design of different types of bridges including substructures with relevant codes.
3. To provide knowledge for construction, inspection and maintenance of bridges.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Illustrate** types of bridges, their components and selection of bridge site	III	Applying
CO2	**Analyze** various types of bridges with appropriate loads and methods	IV	Analyzing
CO3	**Design** of bridges and bearings along with reinforcement details	VI	Creating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	1	2	3	4	5	6
CO1			2	3		2
CO2			2	2	1	2
CO3			2	2	1	2

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	Marks

ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:	
Module 1: Introduction to Bridge	**5 Hrs.**
Components of bridge, Importance of bridge, Types of bridges, Selection of bridge type and site, Economic span, Superstructure – Alignment, Drainage, Clearance, Road curb.	
Module 2: Analysis of Culverts	**7 Hrs.**
Design loads for bridges, IRC Loading, Design of RC Culvert, Pipe culvert, Box culvert.	
Module 3: RC Deck Slabs	**8 Hrs.**
Design of RC deck slab, Beam and slab, T-beam bridge, Pigeaud’s theory, Corbon’s theory, Balanced cantilever bridge.	
Module 4: Prestressed Concrete Bridges	**8 Hrs.**
Prestressed Concrete Bridges – General aspects, Advantages, Design of pre-tensioned and post-tensioned concrete bridge decks.	
Module 5: Design of Composite Bridges	**6 Hrs.**
Design of composite bridges, Reinforced concrete slab on steel plate girder, Stiffeners, Shear connectors, Connections.	
Module 6: Design of Substructure	**5 Hrs.**
Design of substructure – Abutment, Pier, Approach slab, Pile and well foundation. Bearings and expansion joints.	
Module wise Outcomes At end of each module students will be able to: 1. Choose suitable bridge type depending upon site conditions. 2. Design the different types of culverts. 3. Design different types of RC bridges using different theories subjected to IRC loading. 4. Analyze and design prestressed concrete bridges. 5. Analyze and design composite bridges. 6. Design components of substructure.	

Title of the Course: Professional Elective 3 Design Optimization (4ST532)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Engineering Mathematics, Structural Analysis and Design

Textbooks:

1. Singiresu S. Rao, "Engineering Optimization-Theory and Practice", New Age International Publishers, 2013, 4th Edition.
2. Uri Kirsh, "Optimum Structural Design", McGraw Hill, 1988.
3. R. Fletcher, "Practical Optimization", John Wiley & Sons, New York, 2nd Edition, 1987.

References:

1. Edgar, Himmelblau and Lasdon, "Optimization of Chemical ProcessesMc", Graw Hill International Edition, 2nd Edition, 2001.
2. M.S. Bazaraa, H.D. Sherali and C. Shetty, "Non-Linear Programming-Theory and Algorithms", John Wiley and Sons, New York, 1993.
3. Richard Vinter, "Optimal Control", Springer, 2010.

Course Objectives:

1. To provide knowledge of optimization approach and significance of optimization.
2. To impart knowledge of application of optimization tools required for analyzing and solving problems in structural and other engineering fields.
3. To provide exposure to modern techniques of global optimization for design optimization of Processes/Designs in engineering field in general and structural engineering.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Apply** various optimization techniques for solution of linear, nonlinear and general optimization problems.	III	Applying
CO2	**Analyze** various optimization problems in engineering field.	IV	Analyzing
CO3	**Create** optimized global engineering designs of structural and other engineering facilities having different complexity.	VI	Creating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	1	2	3	4	5	6
CO1	1		2	3		2
CO2			1	2		2
CO3				2	2	2

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	Marks
ISE 1	10
MSE	30

ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Classical Optimization Techniques	**6 Hrs.**
Relevance and Significance of optimization, Various optimization problems in different fields of engineering, Introduction to optimization theory-objective function/design variables/constraints, Classification of optimization problems and optimization techniques, Formulation of Various optimization problems, linear programming and simplex algorithm, Nonlinear programming by Lagrange Multiplier with equality and inequality constraints.	
Module 2: Optimization of Trusses and Structural Components	**6 Hrs.**
Minimum weight criteria, fully stressed design and displacement constraints, optimization of truss, cable and arch structures, optimization of beams and columns.	
Module 3: Constrained Optimization and Multi-Objective Optimization	**8 Hrs.**
Optimality criterion methods. Sequential Quadratic Programming, Penalty Methods, Sensitivity of optimum solution, Aspects of Multi-objective optimizations, Multi-objective optimization techniques.	
Module 4: Optimization by Stochastic and Heuristic Algorithms I	**6 Hrs.**
Particle Swarm Optimization, Introduction, Computational Implementation, Solution of the Constrained Optimization Problem, *Ant Colony Optimization*, Basic Concept, Ant Searching Behavior, Path Retracing and Pheromone, Updating, Pheromone Trail Evaporation, Algorithm. Examples.	
Module 5: Optimization by Stochastic and Heuristic Algorithms II	**6 Hrs.**
Simulated annealing, Procedure, Algorithm, Features of the Method, Optimization solutions. *Response surface methodology*, Three-level factorial design, Box–Behnken design, Central composite design, Doehlert design, Desirability function, Examples.	
Module 6: Optimization by Evolutionary and Fuzzy Algorithms	**8 Hrs.**
Genetic algorithm, Representation of design variables, Representation of Objective Function and Constraints, Genetic Operators, Algorithm flowchart, Design examples. *Fuzzy Set Theory*, Optimization of Fuzzy Systems, Computational Procedure, Numerical Example, Neural-Network-Based Optimization. Taguchi Method.	
Module wise Outcomes At end of each module students will be able to: 1. Apply fundamentals of optimization and important algorithms. 2. Create and solve basic optimization problems in structural and other engineering fields. 3. Create optimized designs by different techniques of constrained programming. 4. Analyze optimization design problems with PSO and ACO. 5. Analyze optimization design problems with SA and RSM. 6. Design algorithm procedure to solve optimization problem by GA/Fuzzy theory.	

Title of the Course: Professional Elective 4 Advanced Prestressed Concrete (4ST535)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Design of Concrete Structures I and II

Textbooks:

1. Krishna Raju N., "Prestressed Concrete", McGraw Hill Education (ISE Editions); 5th Edition 2014.
2. Ramamruth S. "Design of reinforced concrete structures", Dhanpat rai publishing company, 17th Edition 2010.
3. Nagarajan Praveen, "Prestressed concrete designs", Pearson publications, 2013.

References:

1. Lin T. Y. and Burns N. H. "Design of prestressed concrete structures", Wiley publications, 3rd Edition, 2010.
2. Arthur H. Nilson, "Design of prestressed concrete", John Wiley publications, 2nd Edition.
3. IS: 1343 Indian standard code of practice for prestressed concrete BIS New Delhi.

Course Objectives:

1. To illustrate basic concepts and systems of prestressing.
2. To impart knowledge of Prestressed concrete structures.
3. To provide knowledge for design of prestressed concrete structures using prevailing IS codes.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	Bloom's Cognitive	
		Level	**Descriptor**
CO1	**Estimate** losses of prestress due to various causes.	IV	Analyzing
CO2	**Verify** appropriate section using flexure, shear, torsional design approach for prestressed concrete structures.	V	Evaluating
CO3	**Design** prestressed concrete components and structures.	VI	Creating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	1	2	3	4	5	6
CO1			**3**	**3**		**2**
CO2			**2**	**2**		**2**
CO3				**3**	**1**	**2**

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights, respectively.

Assessment	Marks
ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc. MSE: Assessment is based on 50% of course content (Normally first three modules) ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.	
Course Contents:	
Module 1: Introduction	**6 Hrs.**
Basics of pre-stressed concrete, stress concept, strength concept and load balancing concept, systems of prestressing, loss of prestress, Material properties: steel, allowable stresses, relaxation, fatigue.	
Module 2: Analysis of Sections	**6 Hrs.**
Analysis of rectangular sections under flexure at ultimate loads: equations of equilibrium and compatibility and constitutive models, stress block for concrete, solution procedure, minimum and maximum amount of prestressed reinforcement. Analysis of flanged sections under flexure at ultimate loads.	
Module 3: Design of Section	**8 Hrs.**
Design of Prestressed Concrete beams and slabs, Rectangular and I Sections. Choice of cross section: flexural efficiency; Determination of limiting zone; Post-tension in stress. Magnel's graphical method. Design based on ultimate loads. Detailing requirement.	
Module 4: Shear and Torsion	**7 Hrs.**
Analysis and Design for shear and torsion, Analysis for shear: principal stress trajectories of linear elastic beams crack Patters, modes of failure, component of shear resistance. Capacity for web shear cracking capacity for flexural shear cracking. Design of shear reinforcement detailing requirements, design steps. Analysis for torsion behavior of linear elastic beams, crack pattern. Modes of failure, components of torsion resistance.	
Module 5: Anchorage Zone Design	**6 Hrs.**
Calculations for deflection and crack-width, Pretensioned members: Hoyer effect, transmission length, bond length, development length, transverse tensile stresses, end zone reinforcement. Post-tensioned members: Bursting force, anchorage zone reinforcement, bearing stress, design of end block. Circular Prestressing design.	
Module 6: Design of Continuous Beams	**7 Hrs.**
Cantilever beams and Continuous beams, Cantilever beams: choice of cable profile, determination of limiting zone. Continuous beams: advantages and disadvantages, choice of cable profile, analysis for bending moment. Principle of linear transformation, principle of concordant cable.	
Module wise Outcomes At end of each module students will be able to: 1. Compute stresses and losses in prestressed concrete. 2. Analyze flanged section under flexure. 3. Design prestressed concrete rectangular & I section beams. 4. Analyze and design prestressed concrete beams subjected to shear & torsion. 5. Design end block in prestressed concrete beams. 6. Design continuous beams in prestressed concrete.	

Title of the Course: Professional Elective 4 Advanced Earthquake Engineering (4ST536)	L	T	P	Cr
	3	-	-	3

Desirable Courses: Dynamics of Structures

Textbooks:

1. Agarwal P. and Shrikhande M., "Earthquake Resistant Design of Structures", PHI publications, New Delhi, 3rd Edition, 2006.
2. Key David, "Earthquake Design Practice for Buildings", Thomas Telford Publication, London,2nd Edition, 2006.
3. Paulay, T. and Priestley, M.J.N. "Seismic Design of Reinforced Concrete and Masonry Buildings," John Wiley & Sons, 1992.

References:

1. Kelly James M., "Earthquake Resistant Design with Rubber", Springer-Verlag Publication, London, 2nd Edition, 2012.
2. George G. Penelis and Andreas J. Kappos, "Earthquake Resistant Concrete Structures," E & FN Spon, 1997.
3. FEMA-356, "Prestandard and Commentary for the Seismic Rehabilitation of Buildings," Federal Emergency management Agency, 2000.

Course Objectives:

1. To provide knowledge of various concepts of earthquake resistant design of structures.
2. To impart the knowledge of modelling and analysis of structures for displacement-based design.
3. To illustrate seismic behavior and codal provisions for design of various earthquake resistant structures.

Course Learning Outcomes:

CO	After the completion of the course the student should be able to	**Bloom's Cognitive**	
		Level	**Descriptor**
CO1	**Differentiate** various concepts of earthquake resistant design of structures.	IV	Analyzing
CO2	**Calculate** response of structures for displacement and performance-based design.	V	Evaluating
CO3	**Design** earthquake resistant structures based on its performance.	VI	Creating

CO-PO Mapping: (Use 1, 2, 3 as Correlation Strengths)

PO	**1**	**2**	**3**	**4**	**5**	**6**
CO1			**3**	**3**		**2**
CO2				**2**	**1**	**2**
CO3				**3**	**1**	**2**

Assessments:

Teacher Assessment:

Two components of In Semester Evaluation (ISE), One Mid Semester Examination (MSE) and one End Semester Examination (ESE) having 20%, 30% and 50% weights respectively.

Assessment	**Marks**

ISE 1	10
MSE	30
ISE 2	10
ESE	50

ISE 1 and ISE 2 are based on assignment/declared test/quiz/seminar etc.

MSE: Assessment is based on 50% of course content (Normally first three modules)

ESE: Assessment is based on 100% course content with 60-70% weightage for course content (normally last three modules) covered after MSE.

Course Contents:

Module 1: Concepts of Earthquake Resistant Design	**6 Hrs.**
Force based vs. displacement-based design, performance-based design, seismic input characteristics and their effect on seismic design, comparative study of different national codes.	
Module 2: Modelling and Analysis of Structures for Displacement Based Design	**6 Hrs.**
Back-bone curve, Idealized component models, estimation and modelling of stiffness, strength and ductility of RC, steel and masonry structures, nonlinear static and dynamic analyses.	
Module 3: Direct Displacement Based Design	**8 Hrs.**
Structure performance objectives, performance levels and limit states; P-Delta effects; Torsion; Capacity design for direct displacement-based design.	
Module 4: Performance Based Design	**7 Hrs.**
Structural and non-structural performance, quantification of performance, performance evaluation of structures, services and equipment.	
Module 5: Overhead Water Tanks	**6 Hrs.**
Modelling and analysis of overhead water tanks, hydrostatic and hydrodynamic effects, earthquake resistant provisions.	
Module 6: Cooling Towers	**7 Hrs.**
Seismic behaviour and design of cooling towers, chimneys and silos; Seismic analysis and design of hyperbolic cooling towers, axisymmetric bodies subjected to non-axisymmetric loads, analysis and design of short and tall stacks & chimney structures, foundation compliance, codal provisions.	

Module wise Outcomes

At end of each module students will be able to:

1. Apply various concepts of earthquake resistant design of structures.
2. Analyze structures by modelling for displacement-based design.
3. Evaluate the performance of structures for direct displacement-based design.
4. Evaluate structural and non-structural performance of structure.
5. Design earthquake resistant overhead water tanks by applying codal provisions.
6. Design earthquake resistant cooling towers, chimneys, silos by applying codal provisions.